

## CLAIMS

What is claimed is:

1. A method for differentiating congestion-related packet loss versus random packet loss in a wireless data connection, comprising:

5 monitoring changes in the length of a transmission queue in a wireless data connection;

designating packet loss as being due to congestion if said packet loss is preceded by an increase in the queue length; and

10 designating packet loss as random loss if said packet loss is not preceded by an increase in the queue length.

2. A method as recited in claim 1, further comprising:

15 applying a collision avoidance algorithm if packet loss is designated as due to congestion.

3. A method as recited in claim 2, wherein said collision avoidance algorithm comprises reducing the sender's transmission window by one-half.

4. A method as recited in claim 1, further comprising:

20 monitoring changes in the length of said queue over an interval substantially equal to the amount of time it takes to transmit a window of data packets and receive acknowledgements corresponding to all data packets transmitted in the window.

5. A method as recited in claim 4, further comprising:

initializing a state count to zero;

transitioning from the state count zero to state count one if the length of said

5 queue increases during the next interval;

transitioning from the state count one to state count zero if the length of said

queue decreases or remains steady during the next subsequent interval;

transitioning from state count one to state count two if the length of said queue  
increases during the next subsequent interval; and

10 designating packet loss as due to congestion if state count two is reached.

6. A method as recited in claim 5, further comprising:

applying a collision avoidance algorithm if packet loss is designated as due to  
congestion.

15 7. A method as recited in claim 6, wherein said collision avoidance algorithm  
comprises reducing the sender's transmission window by one-half.

8. A method as recited in claim 1, further comprising determining whether  
20 congestion is developing in the forward or reverse path of the connection.

9. A method as recited in claim 8, further comprising isolating forward throughput from congestion on the reverse path.

10. A method as recited in claim 9, wherein congestion is determined by calculating the relative delay that one packet experiences with respect to another as it traverses the connection.

11. A method as recited in claim 10, wherein said relative delay is used to estimate the number of packets residing the in the queue.

12. A method as recited in claim 11, further comprising keeping the number of packets in the queue at a minimum level by adjusting a congestion window.

13. A method as recited in claim 12, further comprising:  
reducing the congestion window if the queue length increases; and  
increasing the congestion window if the queue length decreases.

14. A TCP-based congestion management protocol for a wireless data connection, comprising:

monitoring changes in the length of a transmission queue in a data connection;  
designating packet loss as being due to congestion if said packet loss is preceded by at least two consecutive intervals of increasing queue length; and

designating packet loss as random loss if said packet loss is not preceded by at least two consecutive intervals of increasing queue length.

15. A method as recited in claim 14, further comprising:

5 applying a collision avoidance algorithm if packet loss is designated as due to congestion.

16. A method as recited in claim 15, wherein said collision avoidance algorithm comprises reducing the sender's transmission window by one-half.

10 17. A protocol as recited in claim 16, wherein each said interval comprises the amount of time it takes to transmit a window of data packets and receive acknowledgements corresponding to all data packets transmitted in the window.

15 18. A protocol as recited in claim 17, further comprising:

initializing a state count to zero;

transitioning from the state count zero to state count one if the length of said queue increases during the next interval;

20 transitioning from the state count one to state count zero if the length of said queue decreases or remains steady during the next subsequent interval;

transitioning from state count one to state count two if the length of said queue increases during the next subsequent interval; and

designating packet loss as due to congestion if state count two is reached.

19. A protocol as recited in claim 18, further comprising:

applying a collision avoidance algorithm if packet loss is designated as due to

5 congestion.

20. A protocol as recited in claim 19, wherein said collision avoidance

algorithm comprises reducing the sender's transmission window by one-half.

10 21. A protocol as recited in claim 14, further comprising determining whether

congestion is developing in the forward or reverse path of the connection.

22. A protocol as recited in claim 21, further comprising isolating forward

throughput from congestion on the reverse path.

15 23. A protocol as recited in claim 22, wherein congestion is determined by

calculating the relative delay that one packet experiences with respect to another as it

traverses the connection.

20 24. A protocol as recited in claim 23, wherein said relative delay is used to

estimate the number of packets residing the in the queue.

25. A protocol as recited in claim 24, further comprising keeping the number of packets in the queue at a minimum level by adjusting a congestion window.

26. A protocol as recited in claim 25, further comprising:

reducing the congestion window if the queue length increases; and  
increasing the congestion window if the queue length decreases.

27. A method for differentiating congestion-related packet loss versus random packet loss in a wireless data connection, comprising:

monitoring changes in the length of a transmission queue in a wireless data connection over an interval substantially equal to the amount of time it takes to transmit a window of data packets and receive acknowledgements corresponding to all data packets transmitted in the window;

designating packet loss as being due to congestion if said packet loss is preceded by an increase in the queue length; and

designating packet loss as random loss if said packet loss is not preceded by an increase in the queue length.

28. A method as recited in claim 27, further comprising:

applying a collision avoidance algorithm if packet loss is designated as due to congestion.

29. A method as recited in claim 28, wherein said collision avoidance algorithm comprises reducing the sender's transmission window by one-half.

30. A method as recited in claim 27, further comprising:

5 initializing a state count to zero;

transitioning from the state count zero to state count one if the length of said queue increases during the next interval;

transitioning from the state count one to state count zero if the length of said queue decreases or remains steady during the next subsequent interval;

10 transitioning from state count one to state count two if the length of said queue increases during the next subsequent interval; and

designating packet loss as due to congestion if state count two is reached.

31. A method as recited in claim 30, further comprising:

15 applying a collision avoidance algorithm if packet loss is designated as due to congestion.

32. A method as recited in claim 31, wherein said collision avoidance algorithm comprises reducing the sender's transmission window by one-half.

20 33. A method as recited in claim 27, further comprising determining whether congestion is developing in the forward or reverse path of the connection.

34. A method as recited in claim 33, further comprising isolating forward throughput from congestion on the reverse path.

5 35. A method as recited in claim 34, wherein congestion is determined by calculating the relative delay that one packet experiences with respect to another as it traverses the connection.

10 36. A method as recited in claim 35, wherein said relative delay is used to estimate the number of packets residing the in the queue.

37. A method as recited in claim 36, further comprising keeping the number of packets in the queue at a minimum level by adjusting a congestion window.

15 38. A method as recited in claim 37, further comprising:  
reducing the congestion window if the queue length increases; and  
increasing the congestion window if the queue length decreases.

20 39. A TCP-based congestion management protocol for a wireless data connection, comprising:  
monitoring changes in the length of a transmission queue in a data connection  
over an interval substantially equal to the amount of time it takes to transmit a window of



data packets and receive acknowledgements corresponding to all data packets transmitted in the window;

designating packet loss as being due to congestion if said packet loss is preceded by at least two consecutive intervals of increasing queue length; and

5       designating packet loss as random loss if said packet loss is not preceded by at least two consecutive intervals of increasing queue length.

40.     A method as recited in claim 39, further comprising:

10       applying a collision avoidance algorithm if packet loss is designated as due to congestion.

41.     A method as recited in claim 40, wherein said collision avoidance algorithm comprises reducing the sender's transmission window by one-half.

15       42.     A protocol as recited in claim 41, further comprising:

initializing a state count to zero;

transitioning from the state count zero to state count one if the length of said queue increases during the next interval;

20       transitioning from the state count one to state count zero if the length of said queue decreases or remains steady during the next subsequent interval;

transitioning from state count one to state count two if the length of said queue increases during the next subsequent interval; and

designating packet loss as due to congestion if state count two is reached.

43. A protocol as recited in claim 42, further comprising:

applying a collision avoidance algorithm if packet loss is designated as due to

5 congestion.

44. A protocol as recited in claim 43, wherein said collision avoidance

algorithm comprises reducing the sender's transmission window by one-half.

10 45. A protocol as recited in claim 39, further comprising determining whether congestion is developing in the forward or reverse path of the connection.

46. A protocol as recited in claim 45, further comprising isolating forward throughput from congestion on the reverse path.

15 47. A protocol as recited in claim 46, wherein congestion is determined by calculating the relative delay that one packet experiences with respect to another as it traverses the connection.

20 48. A protocol as recited in claim 47, wherein said relative delay is used to estimate the number of packets residing the in the queue.

49. A protocol as recited in claim 48, further comprising keeping the number of packets in the queue at a minimum level by adjusting a congestion window.

50. A protocol as recited in claim 49, further comprising:

5 reducing the congestion window if the queue length increases; and  
increasing the congestion window if the queue length decreases.

51. A method for improving TCP performance over a wireless connection, comprising:

10 detecting the initial stages of congestion in the connection, and identifying the direction of the congestion;

determining whether congestion is developing in the forward or reverse path of the connection;

15 isolating the forward throughput from events such as congestion that may occur on the reverse path;

determining congestion by calculating the relative delay that one packet experiences with respect to another as it traverses the network;

using said relative delay to estimate the number of packets residing in a bottleneck queue;

20 keeping the number of packets in the bottleneck queue at a minimum level by adjusting the TCP source's congestion window;

reducing the congestion window if the bottleneck queue length increases; and

increasing the congestion window when the source detects additional bandwidth availability in the connection.

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